RECONSTRUCTION OF POROSITY PROFILE IN AN OFFSHORE WELL

G. Montegrossi (*), *O. Vaselli* (**), *B. Cantucci*(***), *F. Quattrocchi* (***)

(*)*CNR-IGG, Sezione di Firenze, La Pira, 4 – 50121 Firenze (Italy)*

(**)*Dipartimento di Scienze della Terra, Università degli Studi di Firenze, Via La Pira, 4 – 50121 Firenze (Italy)*

(***)INGV, *Via Vigna Murata, 605 – 00143 Roma (Italy)*

Summary

We presents the results of a new approach for the reconstruction of thermo-physical properties of deep well from the well log and mineralogical analisys of the outcrops formation. This kind of procedure are generally new, and they are useful for creating the background data for reservoir engeneers and geochemist for modelling a well in order to asses its properties prior of re-opening the well itself for industrial use, such as CO_2 sequestration. We used the temperature profile obtained from the well log and the bulk mineralogy analysed from the corresponding formation outcrops. The profile of thermal capacity and conductivity, and porosity and permeability as well, result well constrained and detaile for further use.

Introduction

Porosity is a very important parameter for reservoir engeneers and for geochemist, because it allows to compute the reservoir storage capacity and the water/rock ratio. A common problem while working with closed wells is to obtain data on the thermo-physical properties of the rock; usually the available well-log report the temperature profile measured during drilling, the mud-loss and some other information on water and gas phase presence. In this work we present a procedure that allow to estimate porosity and permeability of the rock formation from the well-log data joint with a rough mineralogical analisys of the corresponding fomation outcrop with the use of a boundary condition such as surficial heat flow; a similar approach were presented from some authors that dealt with similar problems e.g. Singh V.K., 2007.

Bulk mineralogy via XRD Rietveld

In his work we sampled the outcrop for each formation found in a case-study offshore well situated in the medium tirrenean sea; the stratigraphy of the well is presented in Table 1. The analisys of the rock sample proceed by using a calcimetry with Dietrich-Fruhling apparatus in order to analyse the carbonate content of each sample, and an XRD rietveld analisys in oder to quantify the major mineralogy of each sample and to apply the dolomite correction to the results of calcimetry determination. Rietveld quantification procedure were performed by using Maud v2.2. After separation of clay minerals according to ??? , the clay were quantified by weigting the separate materials once dryed and recognised via XRD analisys of the "Tal Quale", Glycol-treated and 450 and 600°C thermal treated samples. For the purpose of this work, Montmorillonite, Illite and Chlorite were grouped togheter since they present very similar thermo-physical properties; with the same idea we grouped the small amount of Gypsum and Anhidrite found at the top of the "Burano" formation; results are reported in Table 2.

Modelling approach

The key concept of the models is that, once known the mineralogy of each strata, a strict relationship could be established between thermal capacity and conductivity and porosity and permeability. The thermal properties could be computed simply using a weighted sum of the thermal properties of each minerals, using a 1% porosity as initial value, from literature data. In fact, being the well offshore, we could reasonably assume that the pore are filled with water, that have thermal properties sensibly different from minerals, and while increasing porosity the thermal capacity and conductivity decrease. The limit of this model is the assumption of no convective heat transport, that is valid up to permeability of 10^{-12}m/s. At this point we have thermal properties expressed as a funcion of porosity.

Correlation model between porosity and permeability are well known, and they are function of the main mineralogical composition of each strata. On the basis of the mineralogical analisys reported in table 2, we decided to use a clay coating for the upper formation and the calcite coating for the other formation. A coating model assume the presence of small channel whose tortuosity and connectivity are function of the filling material, that is calcite or clay in our assumption, with a correction for the presence of quartz as vein filler material. A resume of the correlation models is reported in table 1.

Once established a correlation model between porosity and permeability, the porosity is the only independent variable of our system. For the calculation we used the software SHEMAT, that allow to take into account all the consideration expressed above and also to compute the heat flow due to fluid advection. As boundary condition we used the surficial heat flow reported in Calore et al. 1988.

With a try-and-error procedure we compute the best fit between our temperature profile and the well-log temperature profile, thus obtaining a porosity profile. The results, togheter wih the initial value, are reported in table 3. From the model we could obtain a detailed temperature, porosity and permeability profile and the thermal properties of each rock formation.

The thermo-physical properties of the well are now well constrained, and we could easily compute the velocity vector field. A further consideration could be introduced: the plasticity of the rock coupled with the hydrostatic pressure (pressure profile is also obtained from the well-log, and it is always nearly hydrostatic pressure) lead to elliptical pore shape, due to the compression along the vertical axis (in the hypotesys of the absence of horizontal forces), and the pore shape act on the velocity vector field projecting narly 75% of the velocity along the horizontal plane. The calculation lead to a velocity field around 1 m/y ($3 * 10^{-8}$ m/s) only in the formation with higher permeability, thus giving a vertical velocity of $0,8 * 10^{-8}$ m/s. Such low velocity confirm our hypothesys of no convective fluid flow. Temperature profile and velocity vector field are reported in Figure 1.

The response of the correlation model if a variation of 3% of the porosity value for each degree of temperature in most sensitive zone; this means that if the temperature of the reservoir is missed by 5°C its porosity change by 1,5%. The sensitivity of this model represent its strenght, but the well-log temperature profile should be well examinated.

REFERENCES

- Calore C., Cataldi R., Celati R., Mongelli F., Squarci P., Taffi L., Zito G.; 1988: *Heat Flow map of Italy*
- Clauser C. & Huenges E.; 1995: *Thermal Conductivity of Rocks and Minerals, Chapter 3 of A Handbook of Physical Constants.* AGU Ref. Shelf 3
- Singh T.N., Sinha S., Singh V.K.; 2007: *Prediction of thermal conductivity of rock through physico-mechanical properties.* Building and Environment, 42, 146–155.

Profondita base	Spessore	Tipologia Roccia	Modello porosita-permeabilita'
310	**Err:529**	Argille	Vol% Clay
572	**262**	Flysh Calcareo	Vol% Clay
2268	**1696**	Flysh Arenaceo	Vol% Clay
2440	**172**	Argilloscisti varicolori	Vol% Clay
2536	**96**	Scisti Policromi	Vol% Clay
2582	**46**	Maiolica e Diaspri	Calcite Coating
2745	**163**	Calcari selciferi	Calcite Coating
2771	**26**	Rosso Ammonitico	Calcite Coating
3140	**369**	Calcare Massiccio	Calcite Coating
3700	**560**	Calcari Rete Avicula	Calcite Coating
3711	**11**	Burano	Anhidrite Coating

Table 1 – Stratigraphy of the case study well with the model used for the correlation between porosity and permeability.

	Calcite	Quartz	Illite II	Dolomite	Anhidrite + Gypsum	Illite + Montmorillonite + Chlorite
Flysh Calcareo	95,2	3,07	0,86			0,84
Flysh Arenaceo	70,41	16,58	5,13	1,76		6,1
Flysh Arenaceo	8,64	56,84	4,76	26,38		3,36
Argilloscisti Varicolori	83,80	5,36	1,71			9,13
Argilloscisti Varicolori	93,80	2,13	1,08	1,11		1,84
Argilloscisti Varicolori	91,70	3,15	1,09			4,06
Scisti Policromi	61,05	35,98	0,46			2,45
Maiolica	95,4	3,36	1,23			0
Diaspri	1,3	96,68	1,18	0		0,84
Calcare Selcifero	66,30	31,40				2,31
Calcare Massiccio	99,41	0,59				0
Calcare Rhaetavicula	74,78	0,6		23,98		0,64
Burano Top	91,15	2,91	1,13	0,2	1,62	2,98

Table 2 – Main bulk mineralogica composition – Illite II is a particular greenish crystalline Illite

Tipologia Roccia	Capacita termica MJ/Kg 25° C	Capacita termica MJ/Kg 135° C	Conducibilita termica W/mk 25° - 1% Porosita	Conducibilita termica W/mk Profilo Finale	Porosita % v/v	Permeabilita m/s
Argille	1,28	1,51	2	1,86	3	3,82E-017
Flysh Calcareo	0,94	1,17	2,6	2,21	3	7,65E-018
Flysh Arenaceo	1,37	1,6	3	2,55	3	7,65E-018
Argilloscisti varicolori	1,17	1,4	2	1,70	3	7,65E-018
Scisti Policromi	0,87	1,1	2	1,70	5	2,04E-017
Maiolica	0,9	1,13	2,5	2,13	5	2,04E-017
Calcari selciferi	0,92	1,15	2,5	2,13	10	2,04E-017
Rosso Ammonitico	0,94	1,17	2,4	2,04	6	1,02E-016
Calcare Massiccio	0,94	1,17	2,4	2,04	10	2,48E-014
Calcari Rete Avicula	0,94	1,17	2,3	1,96	10	2,48E-014
Burano	1,87	2,1	4,8	4,08	6	1,84E-016

Table 3 – Initial and final Thermal capacity and conductivity for each strata and resulting Porosity and Permeability profile.

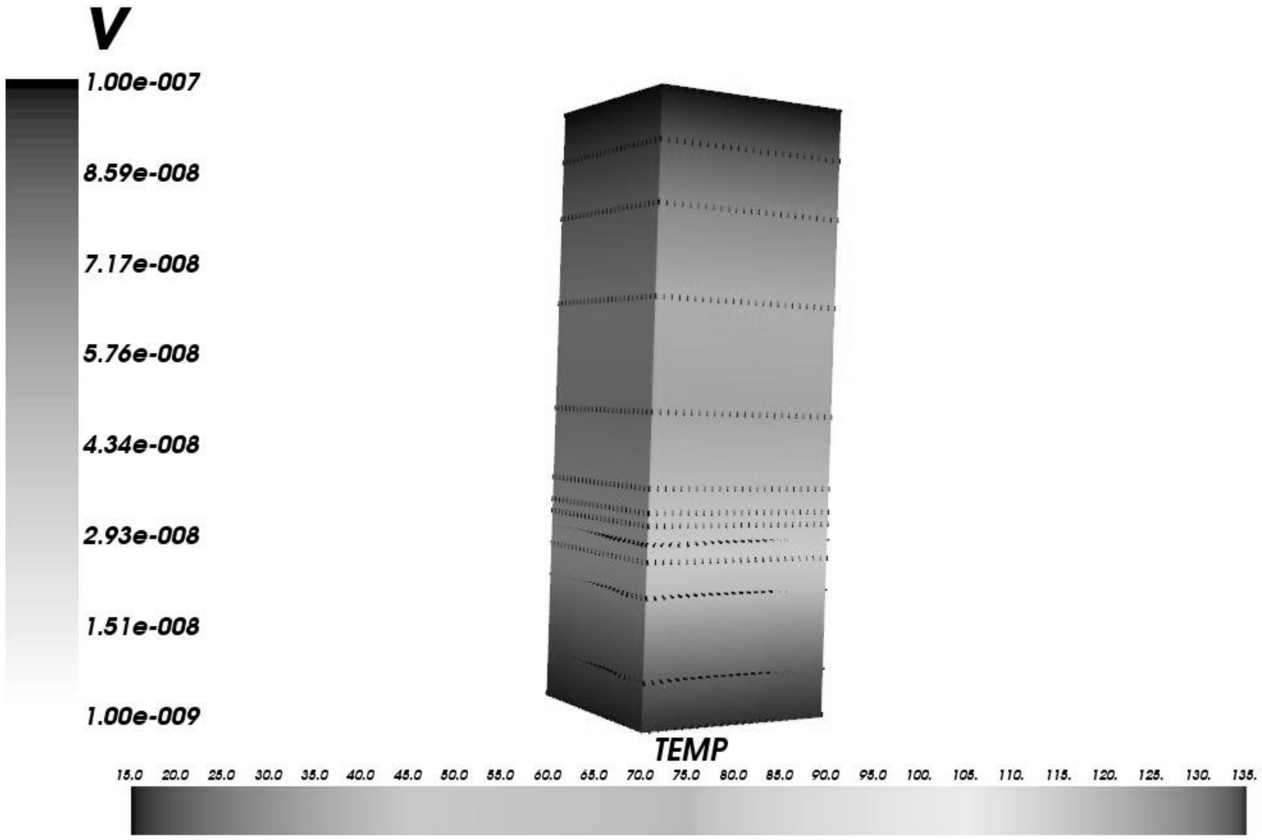

Figure 1 – Temperature profile (T/ °C) and velocity vector field in m/s.